7.0 INSPECTION OF CONCRETE DAMS

7.1 INTRODUCTION

Figure 7-1 A concrete gravity dam in Indiana.

The purpose of safety inspections is to identify deficiencies that potentially affect the safety of the dam. An inspector should develop a methodical procedure for inspecting a concrete dam to ensure that all features and areas are examined and to minimize the amount of time spent in the field. Concrete dams are potentially very stable when designed and constructed properly, and are not usually prone to overtopping failures, erosion, slides, burrowing animals, and piping, all of which are common safety problems at embankment dams. Concrete dams are prone to undermining at the toe due to excessive seepage or soil erosion, and are subject to sudden failure of a segment or piece of the structure.

Figure 7-2 Most concrete dams in Indiana are in-channel structures that are difficult to inspect.

Concrete dams require special visual inspection techniques due to their steep faces. Special safety harnesses, boatswain chairs, boats, video equipment, and scuba divers may be required to complete the inspections.

Most concrete dams in Indiana are in-channel structures that are difficult to inspect because they are continuously inundated with overflow, and typically have a lot of debris on the structure (see Figures 7-2 and 7-3). Sometimes these concrete structures are contained in or along earth embankments.

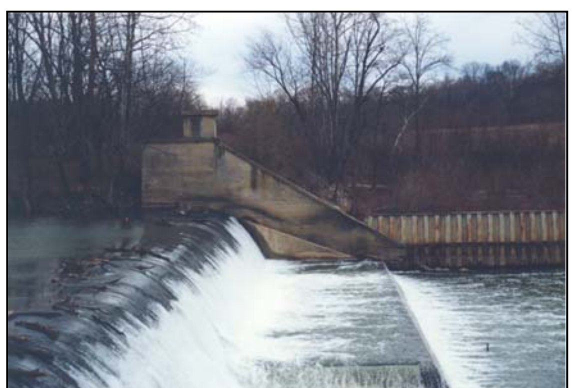

Figure 7-3 Low head, in-channel concrete dams are very dangerous due to the whirlpools, hydraulic jumps, and eddies on the discharge side.

Low head dams constructed across streams and rivers present a safety hazard in the area immediately downstream of the dam. The whirlpools, hydraulic jumps, and eddies created from the discharging water are extremely dangerous to boaters and swimmers, and there have been many drowning accidents that have occurred in such areas. It can be very difficult or impossible for swimmers and boats to escape from this area, especially during periods of increased flow following precipitation events. For this reason, these dams are often referred to as “drowning machines.”

Concrete dams include gravity, arch, roller-compacted, and buttress types. Concrete gravity dams depend on their mass for stability and are generally adapted to sites where there is a reasonably sound rock foundation, or occasionally a dense alluvial foundation. Concrete arch dams are adaptable to sites where the ratio of width between abutments to height of dam is not great and where the foundation at the abutments is solid rock capable of resisting arch thrust. Buttress dams utilize a sloping membrane, generally of concrete, to transmit hydrostatic forces to a series of structural buttresses placed at right angles to the axis of the dam. The most common buttress dams are the flat-slab and multiple arch. Buttress dams are best suited to wide valleys with gradually sloping abutments; they can be founded on rock or sound alluvium. Roller compacted concrete (RCC) dams utilize a relatively new method of construction that combines the safety and benefits of concrete dams with the rapid continuous-placement methods normally associated with earth embankment dams. RCC dams are constructed with zero-slump concrete using vibratory rollers.

The remainder of this chapter describes visual inspection techniques for concrete dams and the concrete portion of dams. Spillways and outfalls on concrete dams (and embankment dams) were described earlier. The information on concrete spillways and outfalls also applies to concrete dams, and should be used as necessary during visual inspections.

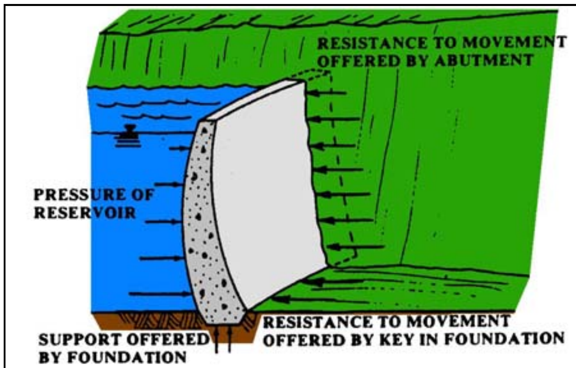

Figure 7-4 Typical forces acting on a concrete arch dam.

7.2 ITEMS OF CONCERN

From a safety standpoint, the principal advantage of concrete dams is that they will not erode during overtopping (although the abutments or foundation could). Embankment slides and piping failures, typical of earth dams, are also prevented by the concrete structure.

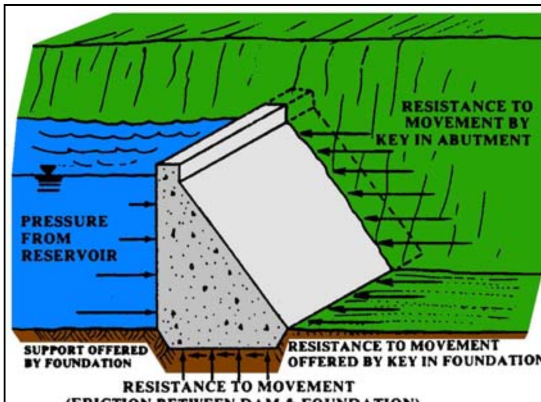

Figure 7-5 Typical forces acting on a concrete gravity dam.

It is important that concrete dam owners are aware of the principal modes of failure and that they are able to discern between conditions which threaten the safety of the dam and those which merely indicate a need for maintenance. Concrete dam design requirements are much different from embankment dams, and generally require more specific expertise to design, construct, inspect, and maintain.

Concrete dams fail for reasons different than embankment dams. Potential problems that may occur are discussed below. If any of these conditions are discovered during a visual inspection, the owner should obtain qualified professional assistance immediately.

The principal items that are potentially hazardous at concrete dams are structural cracking, foundation or abutment weakness, and deterioration. The water in the reservoir exerts substantial hydrostatic forces on the concrete structure, and the concrete structure exerts very large forces on the foundations and abutments.

Damage or failure of a structural component may occur because of an outside condition such as an embankment slide, or meteorologic or seismic event, which has subjected a structure to forces in excess of design. Damage to a structure may also be due to the absence of a formal design, a poor design, or poor construction. Structural problems usually contribute to the dam's susceptibility to failure during normal service.

7.3 CRACKS AND STRUCTURAL PROBLEMS

A crack is a separation of portions of a concrete structure into one or more major parts, and is usually the first sign of concrete distress. Cracks provide openings in the concrete that permit further deterioration of the concrete. A concrete dam and its appurtenances must withstand considerable hydrostatic pressure from the reservoir and groundwater. Hydrostatic pressure acting along cracks through the concrete structure may exert dangerous uplift forces on the structure, possibly leading to lateral propagation of the cracks and uplifting, settlement, sliding of a portion of the structure, and seepage. The inspector should examine all visible concrete surfaces for any signs of cracking, structure movement, and water seepage through the dam.

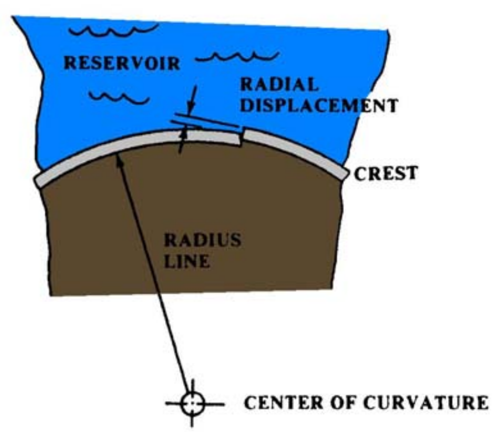

Figure 7-6 Serious cracking in an arch dam, with radial displacement.

Serious threats to concrete dams often involve cracks in the dam, abutments, or foundation. Cracks may develop slowly at first, making it difficult to determine if they are widening or otherwise changing over time.

Even if a crack itself does not present a serious threat, the mechanism causing the

Table 7-1
ACI Standardized Terminology for Individual Concrete Cracks

Direction
Longitudinal
Transverse
Vertical
Diagonal
Random

Width
Fine: less than 0.5 mm
Medium: between 0.5 and 2 mm
Wide: over 2 mm

Depth
Actual depth

Consistent with terminology used for cracking in embankment dams, some nomenclature for cracks in concrete dams differentiates cracks, on and parallel to the crest of a structure - termed longitudinal - from cracks on faces of the structure, which are designated as horizontal. ACI uses the term longitudinal to describe cracks in either location that are parallel to the crest. ACI 201.1, *Guide to Making a Condition Survey of Concrete in Service*, is a useful document that should be used if the inspector needs more information.

crack may threaten the structure. Cracking in concrete may be a visible indication of stress or movement, which the concrete cannot accommodate. The underlying cause of cracking may pose an immediate threat to the dam; therefore, the inspector should make every effort to determine the cause. The inspector must have a thorough understanding of the soil conditions in the foundation and the abutments when determining the cause of cracking.

There are two general categories of cracking typically found on concrete structures: (1) **individual cracks**, and (2) **pervasive cracks**. A concrete structure may have one or a limited number of individual cracks that can be measured and documented during the course of a visual inspection. Or, numerous cracks may be visible within areas of a concrete surface, or the cracking may affect the entire surface. This condition is known as pervasive cracking. Pervasive cracking usually is a sign of concrete deterioration.

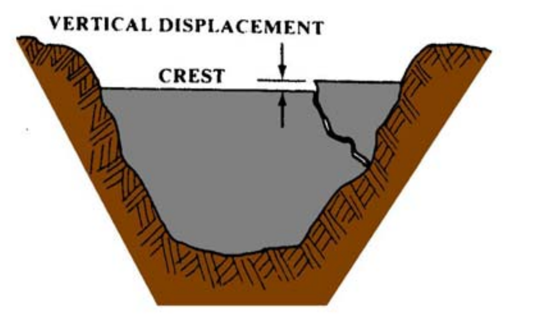

Figure 7-7 Foundation settlement or piping may lead to structural cracking with vertical displacement.

The inspector should carefully examine all visible concrete surfaces for the presence of cracks. If water is seeping from cracks on the downstream face, an underwater inspection of the upstream face may be required, depending on the severity of the problem and the amount of water seeping from the cracks.

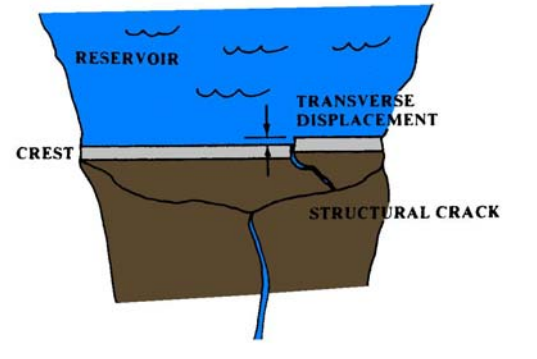

Figure 7-8 Structural crack with transverse displacement and significant seepage.

The American Concrete Institute (ACI) has developed standardized terms to describe the appearance of individual cracks. These terms are listed on Table 7-1; it is recommended that the inspector use this terminology to describe cracks in concrete dams and structures. After the inspector has classified the cracks as either individual or pervasive crack, he/she should then further describe the cracks using the ACI terminology on Table 7-1 for individual cracks, or the terminology described below for pervasive cracks.

ACI uses three general classifications to describe extensive or pervasive cracking of concrete surfaces based on the shape of the cracks: (1) pattern cracking, (2) D-cracking, and (3) checking. Therefore, pervasive cracking should be further classified based on these shape descriptions (see Chapter 6 for sketches). When the concrete exhibits extensive pervasive cracking, the focus of the visual inspection should be the nature and extent of cracking rather than the dimensions of individual cracks.

Deterioration of the mass concrete in a dam can be caused by unusual or extreme stresses within the structure. Once structural movement and cracking have occurred, the damage may continue from freeze-thaw action, chemical action, or from normal weathering of the concrete. The inspector should examine cracks closely for signs of weathering and movement.

Structural cracks are caused by overstressing of portions of the dam, and are usually caused by inadequate design, poor construction techniques, or faulty materials. Structural cracks are often irregular, meaning they run at an angle to the major axes of the dam and may exhibit abrupt changes in direction. These cracks may also have noticeable radial, transverse, or vertical displacement. Overstressing in a concrete dam normally creates areas of distress and cracking that usually can be identified visually during a visual inspection. Cracking, opening of construction joints, changes in leakage rates, and differential movements are all indications of possible overstressing. The overstressing may occur along the foundation because of differential or extreme foundation movements or at any location in the concrete mass of a dam where stresses are excessive. The overstressing may be due to unusual external loading conditions, temperature variations, contraction joint grouting pressures, foundation movement, or excessive uplift pressure in the foundation or along unbonded lift lines.

The amount of displacement associated with structural cracking often varies along the length of a structural crack. This variation usually occurs because a portion of the dam may have moved in relation to the original alignment. In any case, the presence of structural cracks could be an indication of progressive failure of the abutment, the foundation, or the dam itself. The inspector should record the location of the structural cracking, as well as the direction, width, and depth of the crack(s). Qualified professional assistance should be obtained if structural cracks are identified.

Shrinkage cracks often occur when irregularities or pockets in the abutment contact are filled with concrete and not allowed to cure fully prior to placement of adjacent portions of the dam. Subsequent shrinkage of the concrete may lead to irregular cracking at or near the abutment. Shrinkage cracks are also caused by temperature variation. During winter months, the upper portion of the dam may become significantly colder than those portions that are in direct contact with the reservoir water. This results in cracks, which extend from the crest for some distance down each face of the dam. These cracks will probably be at construction joints, if provided. Shrinkage cracks may also be a sign that certain portions of the dam are not carrying a load. The total compressive load must then be carried by a smaller percentage of the structure. It may be necessary to restore load-carrying capability by grouting affected areas.

Construction joints are provided to accommodate volumetric changes, which occur in the structure after concrete placement, and are referred to as "designed" cracks. These joints are so constructed that no bond or reinforcing, except non-bonded waterstops and dowels, extend across the joint. Cracking at construction joints is common, and typically results in spalling and minor leakage. The inspector should examine all joints and look for cracking, spalling, and seepage.

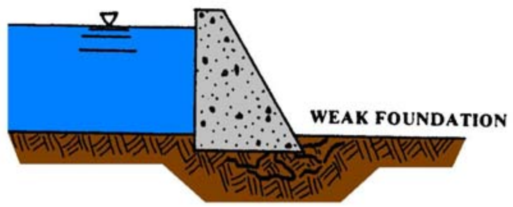

Figure 7-9a A weak foundation may result in foundation and concrete cracking.

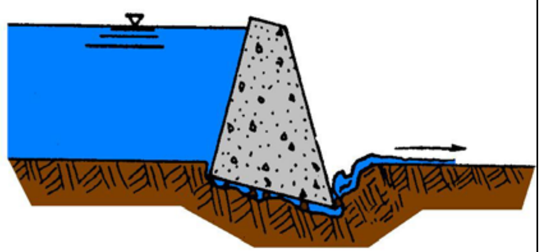

Figure 7-9b Weak foundation soils may result in dam movement and seepage.

Leakage through cracks in concrete dams, although unsightly, is not usually dangerous, unless accompanied by structural cracking. The worst effect may be to promote minor deterioration due to the elements through freeze-thaw action. Increases in seepage could indicate that materials are being leached from the dam and carried away by the flowing water. Decreases in seepage may also occur as mineral deposits are formed in the seepage channel. In neither case is the condition inherently dangerous. Detailed analysis of the problem may be required before it can be determined that repair is necessary for other than cosmetic reasons.

Cracks in the abutments and foundation of a dam may indicate a weak soil or rock zone, settlement due to consolidation, piping of soils or soluble rock from around or beneath the dam, or an overstressing caused by seismic activity or the load of the dam and reservoir. Foundation failure may allow the dam to start to move because of the force of the water behind the structure. In the worst-case scenario, the dam may collapse and allow the water to be released from the reservoir (see Figures 7-9a and 7-9b). The inspector should look for signs of weak foundations, including cracking, dam movement, foundation seepage, and wet, soft foundation soils.

Cracks across a stilling basin or the downstream toe of a concrete gravity dam may indicate sliding of the dam, excessive uplift, or damage from seismic activity. Abutment cracking is of particular concern with concrete arch dams since the loadings on the dam are concentrated at the abutments. The inspector should examine downstream appurtenant structures and abutment

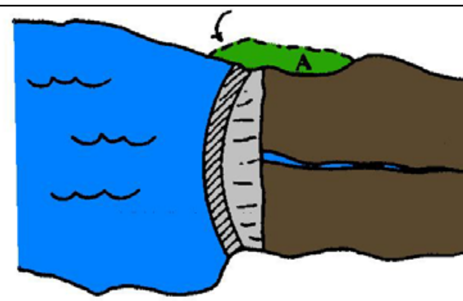

Figure 7-10a A weak area in the left abutment is subjected to large stresses from this arch dam.

contact areas for signs of potential problems.

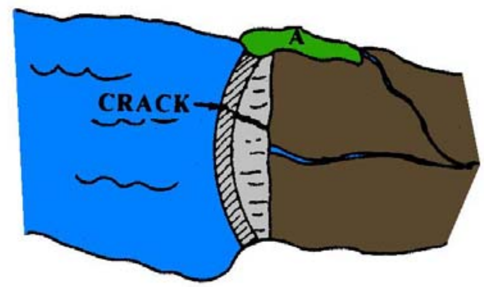

Figure 7-10b Movement of the abutment causes structural cracking in the dam.

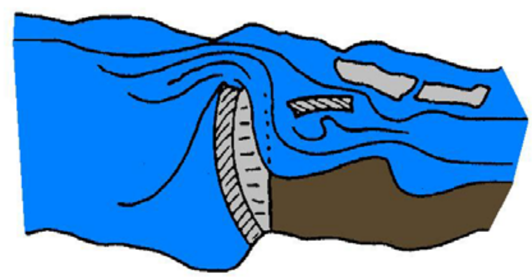
Figure 7-10c Continued abutment movement results in a dam breach.

Concrete dams transfer substantial loads to the abutments and foundation. Although the concrete of the dam may endure, the natural terrain may crack, crumble, or move in a massive slide. If this occurs, support for the dam will be lost, and the dam will fail. Fault planes or weaknesses in the abutment may deteriorate with time, resulting in movement of the natural material in the abutment. Structural cracks in the concrete will be induced as a result of the movement in the abutment. This situation creates the potential for failure of all or a portion of the concrete structure, resulting in the release of reservoir water (see Figures 7-10a, b, and c). If the inspector observes structural cracking, he/she should carefully examine the foundation and abutments for signs of geological stresses or movement. Impending failure of the foundation or abutments is difficult to detect because initial movements are often very small.

The inspector should learn to recognize structural cracks that may affect the safety of the dam. A structural crack compromises the integrity of a concrete structure and therefore may pose a safety problem. In appearance, a structural crack may be:

- Diagonal or random with abrupt changes in direction
- Wide (greater than 0.25 in.), with a tendency to increase in width
- Adjacent to concrete that is noticeably displaced
- Occasionally narrow and diagonal, indicating inadequate design for shear stresses
- Long, single or multiple diagonal cracks with displacement and misalignment

The inspector should always look for seepage in or out of cracks. Water from seepage or leakage may compound the problem, leading to further degradation, including:

- The development of excessive hydrostatic pressures on some portions of the structure
- Attacking the concrete chemically
- Freeze-thaw damage to concrete
- Erosion or solution of the foundation material

- Leaching of the concrete

If cracking is observed during a visual inspection of a concrete dam, the inspector should take the following actions:

- Photograph and record location, depth, length, width, and offset of the cracks. Note prominent cracks, cracking over large areas, and the trends for particular cracks.
- Look for structural damage, including misalignment, settlement, vertical and horizontal displacement.
- Look for any surrounding cracks.
- Classify and describe the cracks using the terminology defined earlier and that shown on Table 7-2.

Table 7-2
Description of Cracks

Individual Cracks	Pervasive Cracks
- Direction - Width - Depth	- Pattern Cracks - D-Cracks - Checking
Hairline Cracks	**Structural Cracks**
- Individual Cracks - Pervasive Cracks	- Individual Cracks are typical

- If extensive new cracking is observed, consider initiating a crack survey to thoroughly document all cracks in the structure and their characteristics. Contact a qualified dam safety professional if there is uncertainty about the severity of cracking or if the following conditions are observed:
  - A major new crack
  - A crack(s) that has changed significantly since the last inspection
  - Cracks indicating movement that might be detrimental to the structure or to equipment operation
  - Significant leakage
  - Look for evidence of seepage or saturated soils in or below the cracks. Also, look for signs of foundation soil erosion. If there is an excessive amount of water flowing through a crack, recommend repairs. Check with a concrete specialist to identify appropriate repair procedures.
- Determine if other dam structures, such as the spillways or outlets, could be affected by the cracking.
- Closely monitor the cracks for changes.
- Try to determine the cause of the cracking; this can help identify effective corrective actions.
- Consult a qualified dam safety professional to determine the cause of the cracking if it is severe or gets progressively worse. Serious cracking or repair operations may require lowering the reservoir level.
- Recommend appropriate corrective action be taken to repair, monitor, or replace the damaged areas. The recommended corrective actions should be consistent with the inspector's training and experience.

If instrumentation has been installed to monitor serious cracks, the data may supply reasons for the cracking. Measurements of leakage and movement are particularly important for evaluating cracks, as well as for evaluating joints, which also are subject to leakage and movement. Reading of an established monitoring network should be performed on a regular basis.

7.4 DETERIORATION

Table 7-3
Common Types of Concrete Deterioration

- Disintegration
- Scaling
- Spalling
- Popouts
- Pitting
- Efflorescence
- Drummy concrete
- Faulty concrete mixes
- Chemical attack
  - Sulfate attack
  - Acid attack
  - Alkali-aggregate reaction
- Metal corrosion
- Erosion
- Joint deterioration
- Cavitation
- Surface defects

Deterioration is any adverse change on the surface or in the body of concrete dams that causes the structure to separate, break apart, or lose strength. A concrete structure cannot be expected to perform properly if it is deteriorated. The term, deterioration, is most commonly used in reference to the general condition of the concrete, and can result in the complete destruction of the material. The amount of deterioration, which has occurred in the concrete, is gaged with respect to its original condition. Deterioration is normally due to the forces of nature such as wetting and drying, freezing and thawing, oxidation, decay, and erosive forces of wind and water. Activities of humans can also contribute to deterioration by altering the chemical composition of water through application of chemicals on or near a dam, and by virtue of the use of the dam (mine tailings, waste storage or retention, and product storage). A subjective evaluation of the extent and possible effects of deterioration should be made. Sometimes deterioration will be complete enough to result in other detrimental conditions such as structural failures of concrete because of reinforcing corrosion. Table 7-3 lists common types of concrete deterioration.

The inspector should use the terms listed on Table 7-3 to describe concrete deterioration. Many of the terms are interrelated, with one type of deterioration producing one or more other types. The use of common terminology will help reviewers to better understand the defects and problems.

Most concrete structures in Indiana experience some form of deterioration due to the severe nature of the climate and the dam environment. Most forms of concrete deterioration develop over a relatively long period of time with visual warning signs. Therefore, there is usually sufficient time to repair the structure before total failure occurs. The most common concrete defects on Indiana dams are normally caused by alkali-aggregate reaction, low aggregate strength, poor design or mix placement, and weathering. The inspector must be able to determine the cause and nature of the deterioration to be able to recommend corrective action.

Deterioration of concrete may be caused by many factors, including weathering, mechanical impacts, internal pressure, drying shrinkage, thermal stress, chemical action, leaching by water seepage, poor concrete mixes, poor concrete design, and freeze-thaw action. Water seeping through cracks in concrete usually leaches calcium from the concrete and forms white, calcium carbonate deposits on the concrete surfaces. It may be difficult to isolate the specific cause for concrete deterioration. If the inspector is not sure, he/she should obtain qualified professional help, or define the potential cause within a range of two or three possible causes. Sometimes, more than one mechanism may be involved. For example, cracking from thermal stress or drying shrinkage may lead to freeze-thaw action or leaching by water seepage.


Figure 7-11 Calcium carbonate deposits on the downstream face of a concrete dam as a result of water seepage.

Severe deterioration can result from a chemical reaction between alkali present in cements and certain forms of silica present in some aggregates. This chemical reaction produces byproducts in the form of silica gels, which cause expansion, and loss of strength within the concrete. Alkali-aggregate reaction is characterized by certain observable conditions, such as random cracking, and by excessive internal and overall expansion or swelling. Additional indications are a gelatinous exudation and whitish amorphous deposit on the surface, and lifeless, chalky appearance of the freshly fractured concrete. The inspector should look for these signs of alkali-aggregate reaction and record the location, extent, and physical characteristics of them. The white exudation from alkali-aggregate reaction should not be confused with white calcium carbonate deposits that are very common on concrete dams as a result of seepage leaching the calcium from the concrete. Table 7-4 describes common signs of alkali-aggregate reaction.

Table 7-4

Early Indicators of Alkali-Aggregate Reaction

- Pattern cracking, usually in areas exposed to wet-dry cycles, such as:
  - Parapets
  - Piers
  - Top of a dam
- Efflorescence
- Incrustation
- White rings around aggregate particles
- Gel-like substance exuded at:
  - Cracks
  - Pores
  - Openings
- Swelling of concrete

Signs of Severe Alkali-Aggregate Reaction

- Disbonding of blocks at lift lines
- Binding of gates
- Severe cracking
- Loss of strength and ultimate failure of the structure

Alkali-aggregate reaction is a chemical reaction that takes place in the presence of water. Surfaces exposed to the elements or dampened as a result of through dam seepage will demonstrate the most rapid deterioration. Once suspected, the condition can be confirmed by a series of tests performed on cores drilled from the dam. Although the process of deterioration is gradual, alkali-aggregate reaction cannot be economically corrected by any means now known. Continued deterioration often requires total replacement of the structure. If a highly active aggregate is used without proper low-alkali cement, the reaction between the aggregate and cement can cause swelling of the mass concrete, creating surface cracking and deterioration. This expansion of the concrete can also cause binding of gates, valves, and operating equipment, and deterioration of the concrete at metal-work supports.

Alkali-aggregate reaction can also lead to deterioration well into the mass of the concrete dam by disbonding blocks along construction joints. The reduction of strength resulting from disbonding, combined with a buildup of hydrostatic pressure along the open construction joints can affect the integrity of the dam. Besides alkali-aggregate reaction, deterioration of concrete can also be caused by other chemical reactions such as inorganic acids, sulfates, and other salts.

Low aggregate strengths or poor bonding characteristics of cement can produce low-strength concrete, which can cause cracking, spalling, or areas of distress in a dam. Aggregates with high absorption characteristics are highly susceptible to freeze-thaw damage. Aggregate, which has been contaminated by silt, clay, mica, coal, wood fragments, organic matters, chemical salts, or surface coatings, will produce concrete of low strength and durability. Minerals in the mixing water can also prevent the production of sound concrete.

Disintegration by weathering is caused mainly by the disruptive action of freezing and thawing, and by expansion and contraction, under restraint, resulting from temperature variations, and alternate wetting and drying. The effect of freeze-thaw action on a concrete dam is usually concentrated near the concrete surface and within exposed structural members. Parapets, cantilevers, top of dam roadway surfaces, stilling basin walls, tunnel or adit portals, and exposed decks and slabs are the most common areas affected by freeze-thaw action. Freeze-thaw action will not normally constitute a dam safety problem except when concrete associated with the water passages, mechanical equipment, or emergency access is affected. The effects of freeze-thaw action, like that of alkali-aggregate reaction, consist of surface deterioration and pattern cracking and can easily be identified by visual inspection. It is, however, sometimes difficult to distinguish between freeze-thaw and alkali reaction except by laboratory tests.

Deterioration of concrete can also result from the soluble products in the concrete being removed by leaching due to faulty concrete or the leachate being highly corrosive. Mineral deposits on the concrete surfaces usually indicate this type of disintegration.

Concrete deterioration can also occur from erosion. The principal causes of erosion of concrete surfaces are cavitation, movement of abrasive material by flowing water, abrasion and impact of traffic, wind blasting, and impact of flowing. Erosion, being a surface type of deterioration, is usually easily identified by a visual examination and its cause is usually evident. Erosion often produces a smooth, polished appearance of the aggregate within the concrete mass.

Surface defects are other concrete deficiencies that may not be progressive in nature; that is, they do not necessarily become more extensive with time. Surface defects are usually shallow and do not normally present an immediate threat to the structure. Most concrete structures typically show signs of surface defects. However, they may make the concrete more susceptible to more significant deterioration. Table 7-5 lists common types of surface defects on concrete structures.

Surface defects may include:

- Shallow deficiencies in the surface of the concrete
- Textural defects resulting from improper construction techniques
- Localized damage to the concrete surface

Table 7-5
Common Surface Defects on Concrete Structures

• **Honeycomb:**	Voids in spaces between coarse aggregate particles. Cause - Poor construction practices: segregation due to improper placement or inadequate vibration.
• **Stratification:**	Separation into horizontal layers, with smaller material concentrated near the top. Possible results include nonuniform strength, weak areas, and disbonding of lifts. Cause - Overly wet or over-vibrated concrete, poor interlayer consolidation {vibration} or cold joints in placement.
• **Form Slippage:**	Slightly offset blocks, uneven joints and surfaces. Cause - Form movement during placement and vibration.
• **Stains:**	Discoloration Cause - Deposits from runoff water, corrosion of exterior steel, spilled construction materials, or curing water with staining qualities.
• **Impact Damage:**	Marred or spalled surfaces. Cause - Blows from moving trucks, boats, cranes, or debris.

If concrete deterioration is observed during a visual inspection of a concrete dam, the inspector should:

- Photograph and record location, type, and extent of the deterioration. Note prominent features, and whether cracking is also present.
- Look for structural damage, including misalignment, settlement, vertical and horizontal displacement.
- Look for any surrounding damage to structures or foundation. The inspector should look closely for changes in the spillways and outlet structures that may be affected by structural damage to the dams. Items to inspect for include vertical, horizontal and lateral displacements, structural cracking, and tilting of spillway walls.
- Classify and describe the deterioration using the terminology previously defined.
- If deterioration is extensive, consider initiating a condition survey or surface mapping to thoroughly document all problems in the structure and their characteristics. Contact a qualified dam safety professional if there is uncertainty about the severity of deterioration.
- Look for evidence of seepage or saturated soils in or below the dam and on the abutments. Also, look for sign of foundation soil erosion. If there is an excessive amount of water, or water, which cannot be handled by the drainage system, is flowing through a crack, recommend repairs. Check with a concrete specialist to identify appropriate repair procedures.
- Determine if other dam structures, such as the spillway or outlet, could be affected by the deterioration that is observed.
- Closely monitor the problems for changes.
- Try to determine the cause of the deterioration; this can help identify effective corrective actions.

- Consult a qualified dam safety professional to determine the cause of the problem if it is severe or gets progressively worse. Serious deterioration or repair operations may require lowering the reservoir level.
- Recommend appropriate corrective action be taken to repair or to replace the damaged spillway or outlet areas. The recommended corrective actions should be consistent with the inspector's training and experience.

Although outlet system deterioration is usually not a problem at concrete dams, the frequency of such damage is higher due to greater average hydraulic head. Visual inspection of the outlet system should be emphasized during inspection of tall concrete dams.

7.5 SPECIAL INSPECTION TECHNIQUES AND REQUIREMENTS

Access and safety are special concerns that need to be planned for in advance of a visual inspection. The conditions normally encountered at concrete dams make it very difficult to gain close access to all features.

The faces of concrete dams are often near vertical, and the site is commonly a steep-walled rock valley. Access to the downstream face, toe area, and abutments may be difficult and usually requires special safety equipment such as safety ropes, or a boatswain's chair. Close visual inspection of the upstream face may also require a boatswain's chair or a boat. Without this equipment, visual inspection of all surfaces of the dam and abutments may not be possible.

Figure 7-12 Concrete dams are usually difficult to inspect.

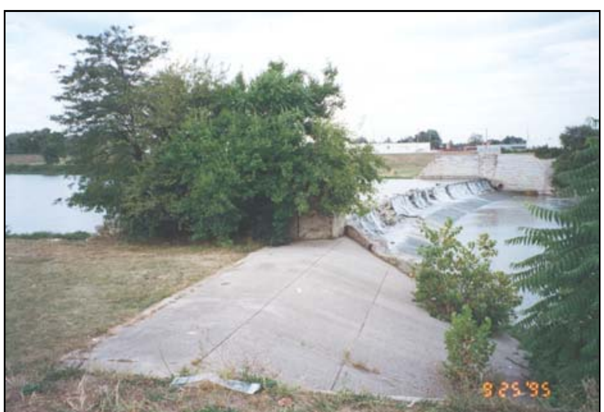

Figure 7-13 Access to this in-channel concrete dam is dangerous.

A boat may be required to access the upstream face that is above the water. In-channel dams such as low head dams, and areas downstream of large outfalls are very dangerous and require extreme caution during visual inspections. The high velocity water current, whirlpools, hydraulic jumps, and eddies that form in these areas can create conditions that trap and sink boats and swimmers. The inspector should always wear life preserver jackets when using a boat. Experienced scuba divers are required if the submerged portion of the upstream face must be inspected. Radio communication between the diver and an experienced inspector on the surface is preferred during this exercise.

Regular visual inspection with a pair of powerful binoculars can initially identify areas where change from surrounding areas is occurring. When these changes are noted, a detailed close up inspection should be performed. Any questionable condition requires immediate evaluation by a qualified dam safety professional. Since the failure of concrete dams can occur suddenly, even a hint of a problem must be evaluated.

Another technique that can be used is videotaping of the entire structure. A high power zoom lens can be used to get close up video footage of the dam faces and discharge structures. The tapes can then be closely examined in the office for visual problems. Problems that are detected may then require closer visual inspection in the field. Problems that may be encountered with this technique include gaining access to points where filming will be effective, and obtaining full and complete coverage.